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Two new *Nilssoniocladus* species from the Jurassic (Oxfordian) Tochikubo Formation, Northeast Honshu, Japan

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Abstract. Two new *Nilssoniocladus* species are erected based on the well preserved specimens collected from the Tochikubo Formation (Oxfordian), Soma-Nakamura Group, Northeast Honshu, Japan. Both *Nilssoniocladus tairae* sp. nov. and *N. japonicus* sp. nov. are represented by long and short shoots terminally with a rosette of leaves. Detached leaves of *Nilssoniocladus* were piled up on the bedding planes, forming so-called '*Nilssonia*' mats which suggest that the leaves of both species are deciduous like those of the type species. The slender habit of long shoots suggests that *Nilssoniocladus* plants are climbers.

Key words : Late Jurassic (Oxfordian), *'Nilssonia', Nilssoniocladus, Northeast* Japan, Ryoseki-type flora

Introduction

Instead of a leaf genus '*Nilssonia*', the genus *Nilssoniocladus* was established by Kimura and Sekido (1975) based on a much more complete specimen consisting of a slender long shoot and helically arranged short shoots. The short shoot gives off a terminal rosette of '*Nilssonia*' leaves. The type species is *Nilssoniocladus nipponensis* (Yokoyama) from the Lower Cretaceous Oguchi Formation in the Inner Zone of Japan. In the type specimen (KM-301U), a long shoot, several short shoots and rosettes of leaves are clearly in organic connection.

The leaves appear to be deciduous, because a number of detached leaves of *Nilssoniocladus nipponensis* proximally with expanded petiole base are seen piled up everywhere, forming thick mats. Judging from the slender habit of the long shoot, this plant was thought to be a climber.

Later, Spicer and Herman (1996) described two species of *Nilssoniocladus*, *N. alaskensis* and *N. chukotensis*, from uppermost Albian-lower Cenomanian beds in Alaska and Chukotka (Russia) respectively.

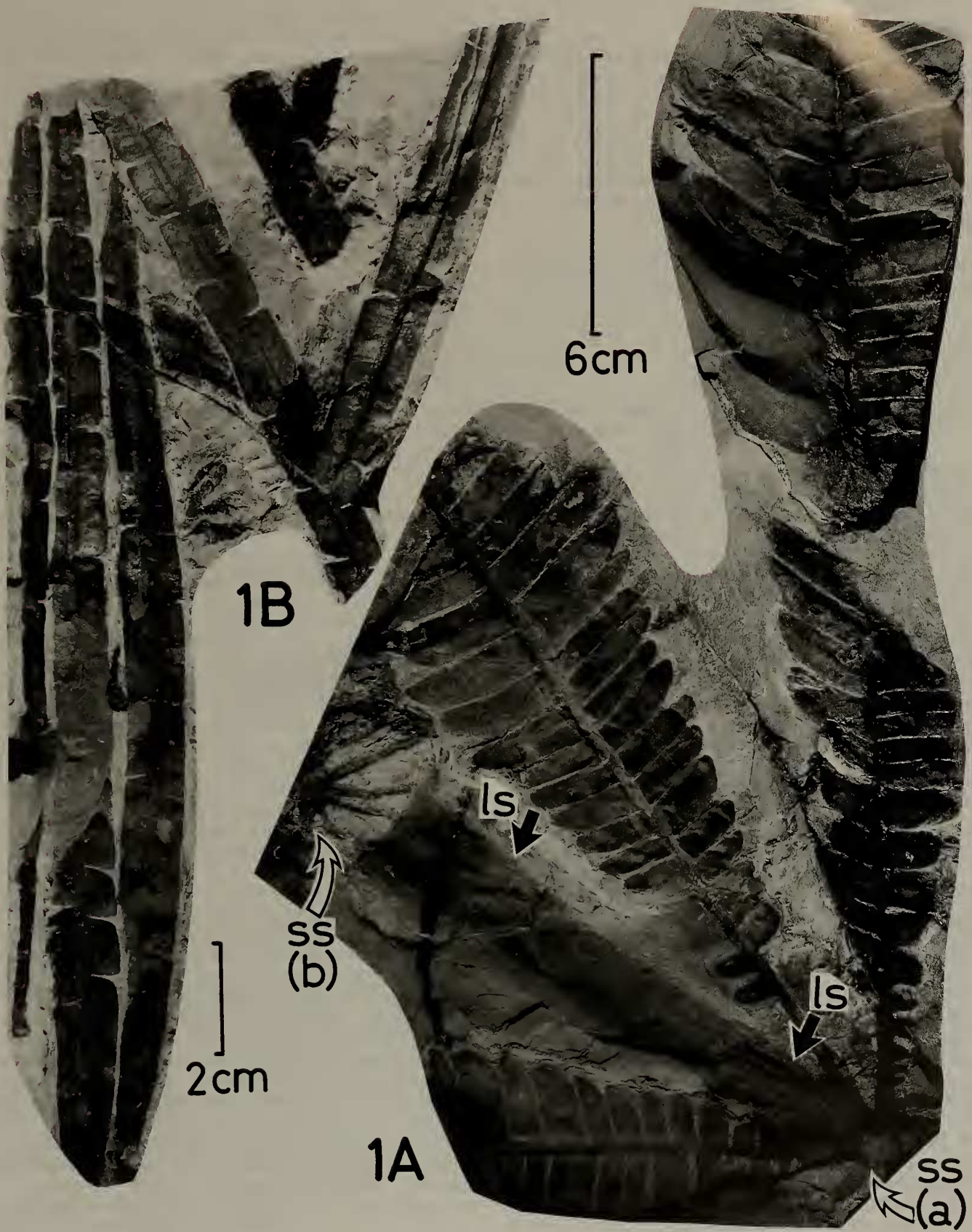
In this paper, we propose two new *Nilssoniocladus* species, *N. tairae* sp. nov. and *N. japonicus* sp. nov., based on newly collected specimens from the fossiliferous Tochikubo Formation, Northeast Honshu, Japan.

The shoots and leaves are sometimes preserved in organic connection. *Nilssoniocladus tairae* bears at least seven leaves terminally to the vertically compressed young short shoot. The leaves of *Nilssoniocladus japonicus* resemble those of '*Nilssonia*' *schaumburgensis* which has been provisionally regarded as '*Nilssonia*' ex gr. *schaumburgensis* (Kimura and Ohana, 1988b) or '*Nilssonia*' sp. cf. '*N*' *schaumburgensis* (Kimura, 1976). They are in organic connection terminally to the vertically compressed young short shoot. In both species, long shoots are poorly preserved, and thus their surface features are uncertain.

The present *Nilssoniocladus* species are associated with various thermophilic Ryoseki-type plant taxa. On the other hand, *Nilssoniocladus nipponensis* (Yokoyama), the type species, is associated with various temperate Tetori-type plant taxa (e.g. Ohana and Kimura, 1995).

Repository.—Specimens utilized and referred in this paper are housed in Kashima History and Folklore Museum, Fukushima Prefecture (KHFM) and Komatsu City Museum, Ishikawa Prefecture ; type specimen of *Nilssoniocladus nipponensis* (Yokoyama) ; KM-301U (KM).

Figure 1. 1A. *Nilssoniocladus tairae* sp. nov. A poorly preserved long shoot (ls) and two short shoots. The lower short shoot (ss-a) bears four terminally disposed leaves, and in the upper short shoot (ss-b), leaf-laminae are missing leaving six petioles (Holotype, KHFM-210007). **1B.** Detached *Nilssoniocladus Japonicus* leaves (formerly regarded as *Nilssonia* ex gr. *schaumburgensis*) (KHFM-210004).


6cm
1B
ls
ss
(b)
ls
2cm
1A
ss
(a)

Stratigraphy

The Upper Jurassic Tochikubo Formation is a nonmarine sequence belonging to the predominantly marine Soma-Nakamura Group. The Tochikubo Formation is about 350 m thick and intercalated between the marine Callovian Yamagami Formation and the marine Oxfordian-Kimmeridgian Nakanosawa Formation. Stratigraphical details of the Soma-Nakamura Group were given previously by Mori (1963) and a survey of its plant taxa was published by Kimura and Ohana (1988a, b).

This paper deals with the description of two *Nilssoniocladus* species discovered recently. A list of definite *Nilssoniocladus* species hitherto known is given in tabular form.

Systematic description

Class Cycadopsida
Order Cycadales
Family Nilssoniaceae Kimura and Sekido, 1975
Genus ***Nilssoniocladus*** Kimura and Sekido, 1975

Type species.—*Nilssoniocladus nipponensis* (Yokoyama) Kimura and Sekido: Lower Cretaceous Oguchi Formation, Itoshiro Group, Tetori Supergroup in the Inner zone of Japan.

Generic diagnosis.—Stem in ultimate parts slender, branched, consisting of long and short shoots, woody. Long shoot with long and smooth internodes, and bearing short shoots spirally. Short shoots covered with spirally placed rhomboidal leaf scars and at apex bearing a group of '*Nilssonia*' leaves. All leaf scars essentially similar, no scale leaf scars among them. Not possible to observe whether short shoots are in the axil of a leaf or of a scale leaf (Kimura and Sekido, 1975, p. 113).

Nilssoniocladus tairae sp. nov.

Figures 1A, 2A-D, 3A

Material.—Holotype: KHFM-210007. Paratype: KHFM-210006 (counterpart of the holotype). Other specimens: KHFM-210005, 210008, 210009, 210011, 210016.

Locus typicus.—Near Koyamada, Kashima-cho, Soma-gun, Fukushima Prefecture (roughly 37°41′46″N, 140°54′16″E).

Stratum typicum.—Tochikubo Formation (Oxfordian), Soma-Nakamura Group (Mori, 1963).

Derivatio nominis.—Specific epithet after Muneo Taira who collected the specimens described here.

Occurrence.—Locally common.

Specific diagnosis.—Long shoot slender, 1.2 cm wide, giving off short shoots, each terminally with a rosette of seven large-sized leaves. Leaf lamina regularly and deeply cut, forming more than 35 pairs of pinnae. Pinnae rectangular with pointed apices. Petiole shorter with 5-6 pairs of small-sized oval or semicircular pinnae. Veins numerous, simple, parallel, and not convergent at pinna apex.

Description.—Long and short shoots are present. Preserved part of long shoot is 16 cm long and 1.2 cm (partly 1.4 cm) wide, with roughly striated surface; no other definite scars have been found on the surface.

Preserved part of short shoot is 1.5 cm in diameter, and about 5 mm long (or high). Crushed rhomboidal petiole scars are rarely observed on the surface of the short shoots (Figure 2B). Terminally, the short shoot gives off at least seven leaves, forming a leaf rosette. Estimated length of the internode between successive short shoots is 18-20 cm. Details of mode of arrangement of short shoots on the long shoot are, however, uncertain.

The leaves are large, oblanceolate, more than 30 cm long and up to 8 cm wide. The rachis is prominent, 3-4 mm wide, and has a short and thick petiole which is less than 1 cm long and 4 mm wide; the base of the petiole is slightly expanded and in organic connection with the top of a short shoot. Leaf lamina is regularly and deeply cut, forming more than 35 pairs of pinnae. Pinnae are typically rectangular; acroscopic margin is nearly straight, and basiscopic margin is rounded apically. The pinnae of the holotype are 41 mm long and 9 mm wide, rarely narrower; those of the proximal 5-6 pairs are small and oval or semicircular (Figure 2A).

Veins are prominent, numerous, simple, parallel, and not convergent at pinna apex; 18 in number in each pinna (22-23 per cm in density).

Leaf cuticle is not preserved, and reproductive organs are not observed.

Remarks.—This new locality of the Tochikubo Formation has yielded a new type of *Nilssoniocladus* leaves as described above. Some leaves are in organic connection to the short shoots of *Nilssoniocladus*, and form a leaf rosette. The leaves also occur as fragments of leaf rosettes in which short shoots are missing. Most parts occur as detached leaves, forming '*Nilssonia*' leaf-mats on the bedding plane. Therefore, the leaves of this species appear to be deciduous. Many leaves have expanded petiole bases. In our new collection, no detached scar of a short shoot has been found on the surface of a long shoot.

We suggest that the short shoots of *Nilssoniocladus tairae* probably belong to a younger development stage, possibly when the plants were two or three years old, because they are shorter in length and not so prominently elongated on the long shoot.

The surface of the long shoot and of the depressed short shoot, and the proximal portions of rachis and petiole are covered with a faded brownish substance. It is probable that these brown stains are due to some resinous substance oozing out from the woody part of the plant.

The abaxial side of the leaves may resemble leaves of bennettitalean *Pterophyllum* and *Ptilophyllum*, in some aspects because the present rachises are markedly exposed in abaxial view. However, laminae of the present leaves completely cover the rachises in adaxial view. This is a characteristic feature of the *Nilssoniocladus* and '*Nilssonia*' leaves.

So far as we know, the leaves of *Nilssoniocladus tairae* are unique in size, shorter petiole and small-sized proximal pinnae.

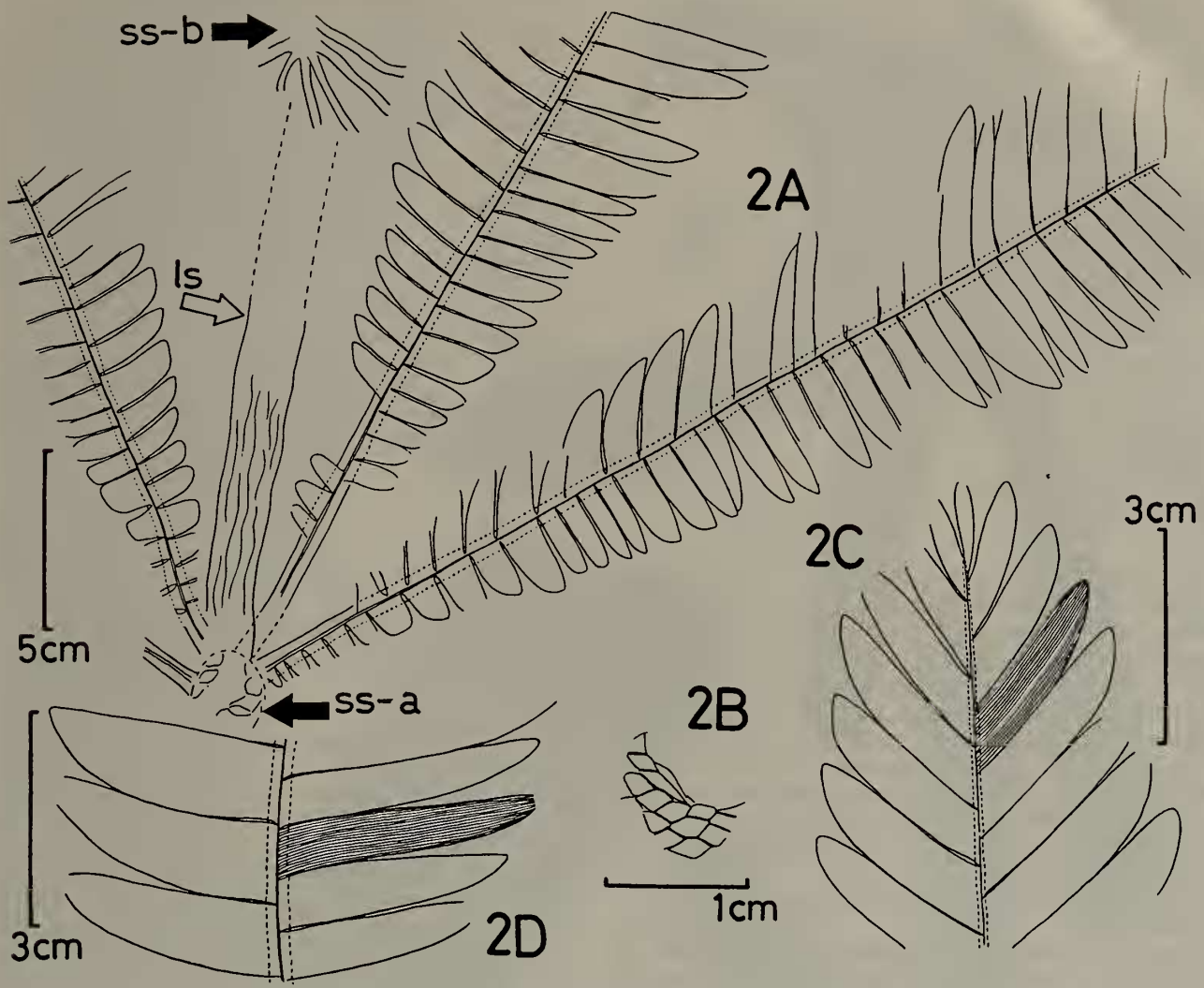


Figure 2. *Nilssoniocladus tairae* sp. nov. **2A.** Drawn on the basis of holotype and paratype. **2B.** Helically disposed rhomboidal petiole bases left around the lateral surface of a short shoot (KHFM210016). Vascular bundles are invisible. **2C.** Apical part of a leaf and venation (KHFM-210011). Pinnae are directed forward. **2D.** Typical pinnae, drawn from the holotype.

Nilssoniocladus japonicus sp. nov.

Figures 1B, 3B-C, 4A-F

Nilssonia ex gr. *schaumburgensis* (Dunker) Nathorst : Kimura and Ohana, 1988b, p. 164, pl. 12, fig. 3 ; pl. 13, figs. 2-6 ; pl. 14, figs. 4-5 ; figs. (text-figs.), 26a-h (Tochikubo Formation).

Material.—Holotype : KHFM-210003. Paratype : KHFM-210002 (counterpart of the holotype). Other specimens : KHFM-210001, 210004, 210018, 210019.

Locus typicus.—Same as *Nilssoniocladus tairae*.

Stratum typicum.—Same as *Nilssoniocladus tairae*.

Derivatio nominis.—After Japan.

Occurrence.—Long and short shoots are rare, but detached leaves formerly regarded as *Nilssonia* ex gr. *schaumburgensis* are quite abundant.

Specific diagnosis.—Each short shoot giving off at least seven leaves. Leaves closely helical at apex of a short shoot, forming a leaf rosette. Leaves long and narrow, nearly parallel-sided, variable in form and size.

Description.—Preserved long shoot is 8 cm long and 7 mm wide with poorly preserved ornamentation on its surface. Short shoot is 1 cm in diameter, and low cylinder-like. The internode between successive short shoots is estimated to be 3.5 cm long.

Leaves are long and narrow, more than 14 cm long and up to 1.3 cm wide, and have rather stout petiole which is 5.5 cm long and 4 mm wide. Seven helically arranged leaves are borne at the top of the short shoot, and form a leaf rosette. Leaf laminae are nearly parallel-sided, completely covering upper surface of prominent rachis. Leaves are variable in form. Some leaves are with entire or irregularly undulated or

Table 1. List of definite *Nilssoniocladus* species. In these species leaf-cuticles and inner anatomical features of the shoots are not preserved.

Nilssoniocladus species (occurrence)	Long shoot	Short shoot	Leaf-type	Reference and age
N. nipponensis (Yokoyama) Kimura and Sekido (Inner zone of Japan)	present	present	*'Nilssonia' nipponensis* Yokoyama (1889)	Kimura and Sekido, 1975; Lower Cretaceous
N. alaskensis Spicer and Herman (Alaska)	present	present	*'Nilssonia' alaskana* Hollick (1930)	Spicer and Herman, 1996; Upper most Albian-lower Cenomanian
N. Chukotensis Spicer and Herman (Chukotka, Russia)	not preserved	present	*'Nilssonia' serotina* Heer (1878)	Spicer and Herman, 1996; Upper most Albian-lower Cenomanian
N. tairae Takimoto, Ohana and Kimura sp. nov. (Northeast Honshu, Japan)	present	present	*Nilssoniocladus tairae* Takimoto, Ohana and Kimura sp. nov.	Takimoto, Ohana and Kimura, this work; Oxfordian
N. japonicus Takimoto, Ohana and Kimura sp. nov. (Northeast Honshu, Japan)	present	present	*'Nilssonia' schaumburgensis* (Dunker) Nathorst-like	Takimoto, Ohana and Kimura, this work; Oxfordian

shallowly dissected margins, some leaves are rather deeply dissected into rectangular segments with truncated distal margins, and some leaves are dissected into semicircular segments (pinnae) (e.g. Kimura, 1976; Kimura and Ohana, 1988b). These leaf-types are specifically inseparable, and may be included in a wide range of continuous intraspecific variation. The largest lamina is more than 17.5 cm long and 2.1 cm wide. Apex is broadly rounded or sometimes shallowly emarginate. The petiole base is expanded laterally. In some cases, several vascular bundle scars (?) are seen in a semicircular row (Figure 4F). Veins are densely crowded, simple, parallel and typically 44 per cm.

Cuticle is not preserved and the reproductive organs are not observed.

Remarks.—The leaves of *Nilssoniocladus japonicus* were found detached and piled up together on the same bedding plane, indicating that they were deciduous.

These detached leaves are similar in form to those originally described by Dunker (1846) as *Pterophyllum schaumburgense* from the Wealden beds of North Germany, and later transferred to *Nilssonia* by Nathorst (1890) based on specimens collected from Lower Cretaceous sites in the Outer Zone of Japan. However, it is still uncertain whether the Japanese leaves are really conspecific with the German leaves or not, because neither preserve cuticles. We provisionally described the detached Japanese leaves as *'Nilssonia'* ex gr. *schaumburgensis* (Dunker) Nathorst or *'Nilssonia'* sp. cf. *'N' schaumburgensis* (Dunker) Nathorst.

Generally, Late Jurassic *'Nilssonia' schaumburgensis*-like leaves in Japan are nearly twice as large as those of Early Cretaceous leaves in Japan. We propose *Nilssoniocladus japonicus* sp. nov. for the Jurassic specimens having larger leaves.

The surface of long and short shoots is also covered with a faded brownish substance of the same probable origin as suggested above.

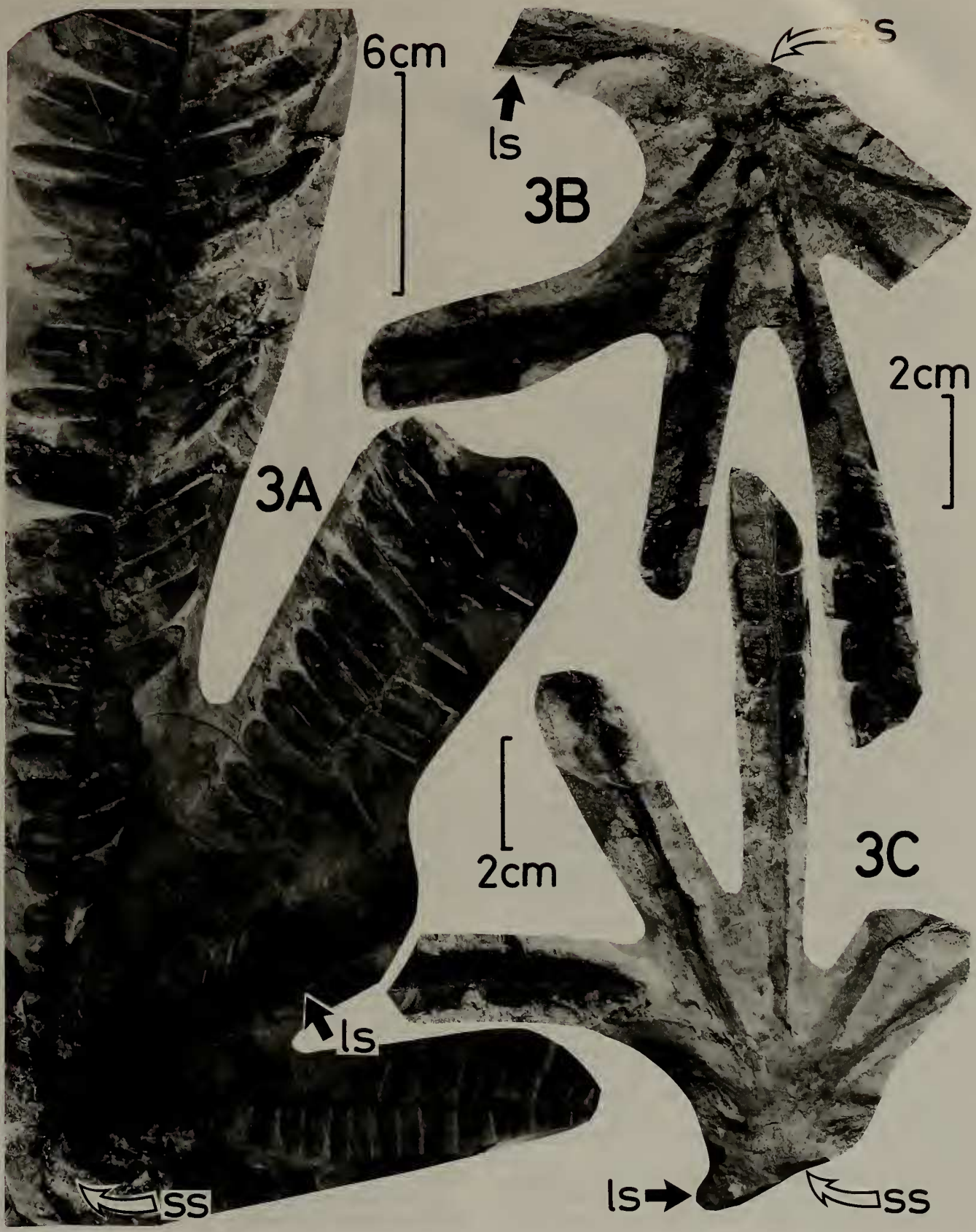
Comparison and discussion

As shown in the original line drawing, the type species *Nilssonicladus nipponensis* has a slender long shoot with a smooth surface (Kimura and Sekido, 1975, text-fig. 1). No surface ornamentation, such as longitudinal wrinkles, short shoot scars and growth increment boundary like those reported for *Nilssoniocladus alaskensis* Spicer and Herman (Spicer and Herman, 1996), has been observed. In *Nilssoniocladus chukotensis* Spicer and Herman, short shoots were shed together with the leaf rosettes (Spicer and Herman, 1996). Such a shedding of short shoots has so far not been recognized in the Japanese species.

There are many plant sites in the Tochikubo Formation, but the occurrence of *Nilssoniocladus tairae* and its detached leaves appears to be restricted to the new locality. Therefore, *Nilssoniocladus tairae* is considered to be a local or endemic species in the Tochikubo Formation.

Matsuo (1976) illustrated mature and developed short shoots terminally with a cluster of three leaves and two scar-like imprints on a slender long shoot from the Lower Cretaceous Oguchi Formation in the Inner Zone of Japan. In his paper (written in Japanese), he regarded these leaves as *Nilssonia nipponensis*, ignoring the established genus *Nilssoniocladus* (Kimura and Sekido, 1975). Although Ma-

Figure 3. **3A.** *Nilssoniocladus tairae* sp. nov. Counterpart of the holotype (paratype, KHFM-210006). **3B, 3C.** *Nilssoniocladus japonicus* sp. nov., **3B:** Long shoot (ls) is poorly preserved. Short shoot (ss) bears terminally seven disposed leaves (Holotype, KHFM-210003), **3C:** Counterpart of the holotype (paratype, KHFM-210002). The long shoot (ls) is hidden below the short shoot.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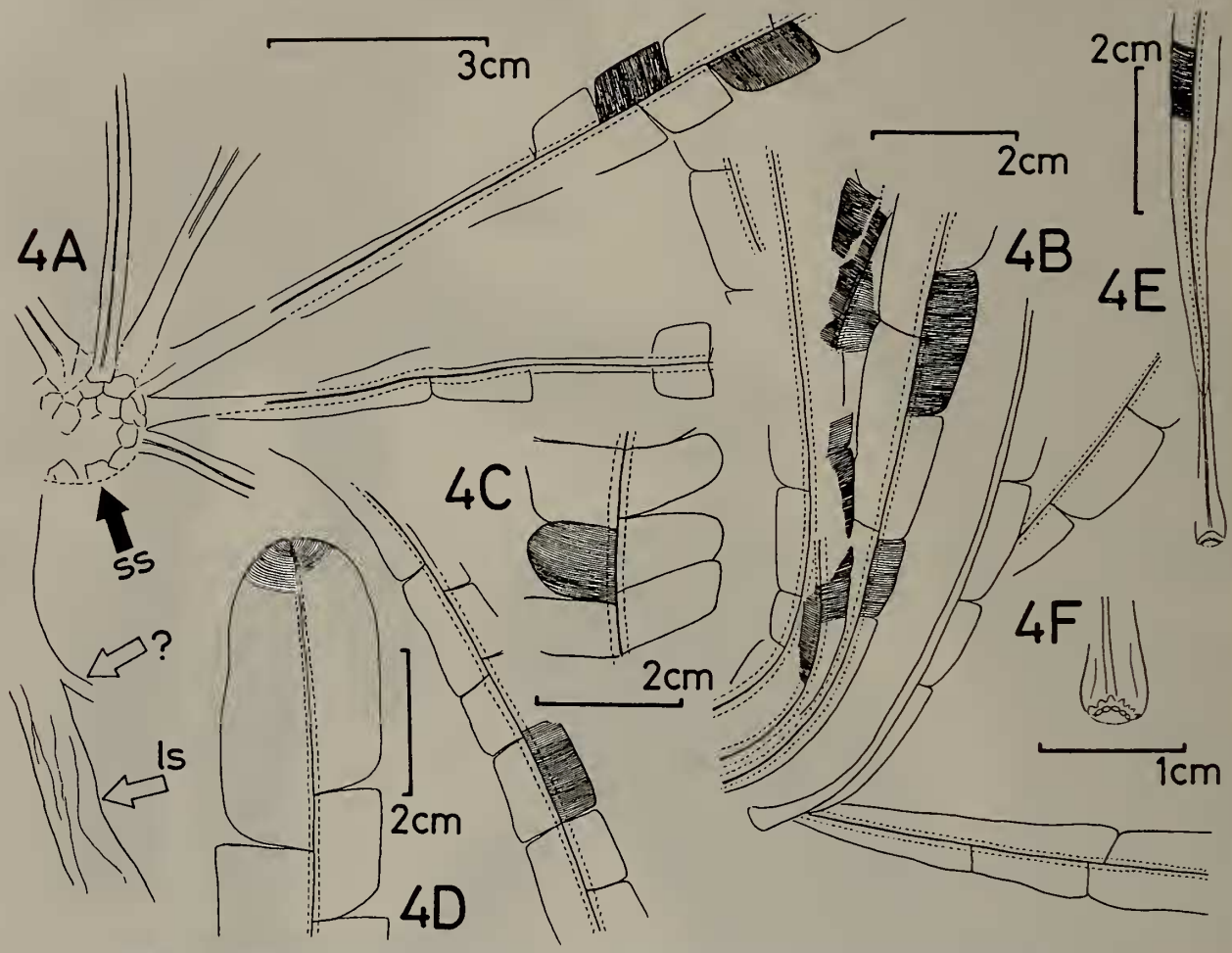

Figure 4. *Nilssoniocladus japonicus* sp. nov. **4A.** Drawn on the basis of holotype and paratype. A projection from the long shoot (arrow ?) is functionally uncertain. **4B.** Detached leaves (KHFM210018). **4C.** Regularly arranged semicircular pinnae of a detached leaf in association with Figure 4D. **4D.** Rounded leaf apex of a large-sized detached leaf and venation, drawn partly from KHFM-210001. **4E.** Lower part of a detached leaf. Lamina of this part is entire (KHFM-210019). Petiole base is expanded and with a clean-cut plane. **4F.** Enlarged from the proximal part of Figure 4E. Several vascular bundle scars (?) are in a semicircular row.

tsuo's line-drawing is simplified, the specimen might belong to *Nilssoniocladus*. The leaves have a characteristic toothed margin and are in our view probably assignable to *Nilssoniocladus lobatidentatus* (Vassilevskaja) known from the Lower Cretaceous of the Lena Basin (e.g. Vassilevskaja *et al.*, 1972). Detached leaves with toothed margin also occur from the Lower Cretaceous of the Tetori Basin in the Inner zone of Japan (Kimura and Sekido, 1976a, b).

Krassilov (1975, fig. 18) illustrated a *Nilssoniocladus*-like shoot with a cluster of leaves, but there are no morphological details.

Nilssonia schaumburgensis (Dunker) described by Watson (1969) from the English Wealden beds includes leaf fragments with preserved cuticle. Its laminae are irregularly and shallowly dissected, and have an emarginate apex. Some leaves are regularly dissected, but the sinuses do not reach to the rachis and the venation is not crowded. Although such English leaves superficially resemble the Japanese leaves of *'Nilssonia'* ex gr. *schaumburgensis* or *'N'* sp. cf. *'N' schaumburgensis*, it is uncertain whether these English leaves are conspecific with the Japanese leaves described here.

The *Nilssoniocladus* plants are considered to be woody climbers, because their slender long shoots bearing the load of large-sized leaf rosettes could not have kept the plants upright.

It is likely that the number of *Nilssoniocladus* species will increase in future. Because we know a number of the tufts

of '*Nilssonia*' leaves hitherto described, all of which seem to converge toward a common point.

An attached table shows a list of definite *Nilssoniocladus* species hitherto known.

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